TABLE 1.

Inclusion	Type	$\delta^{48}Ca$	$(^{26}Al/^{27}Al)_O$	REE patterns
174	Hib (pv, mel)	-3.4 ± 3.3	$<3.3 \times 10^{-6}$	Volatile enriched Group II
181	Hib (pv, sp, fas)	**7.4 ± 2.9**	$(5.4 \pm 0.7) \times 10^{-5}$	Group III
50.2	CaA_2 (pv, mel, fas)	2.3 ± 4.5	$(1.3 \pm 0.7)10^{-5}$	Group II, Yb excess
76	CaA_2 (pv, mel)	-4.1 ± 7.8	—	—
138	CaA_2 (pv, mel)	0.6 ± 4.5	—	—
143	CaA_2 (pv, mel)	4.7 ± 5.6	$(6.5 \pm 3.5) \times 10^{-6}$	LREE fractionated group III
163	CaA_2 (pv, mel)	3.6 ± 4.9	—	—
185	CaA_2 (pv, mel)	**11.7 ± 3.8**	$(3.5 \pm 0.8) \times 10^{-5}$	Volatile enriched Group II
216	CaA_2 (pv, mel, sp)	-2.4 ± 2.0	$(2.1 \pm 0.8) \times 10^{-5}$	Group II
80	CaA_2 (pv, mel) fragm.	-7.0 ± 8.5	—	—

resemble more the hibonite-bearing glass spherules studied by Ireland *et al.* (1990) (4) than the PLACs. There is no relationship between REE patterns and other properties. The two CAIs with ^{48}Ca excesses have completely different patterns and so have two CAIs (143 and 216) whose mineralogy, size and texture are similar, distinguishing them from the other CAIs. They consist of a fine-grained intergrowth of pure CaA_2 and gehlenitic melilite with a texture reminiscent of sintering. A remarkable feature is the sizeable fractionation in the LREE La to Sm, most extreme in the examples of Fig. 1. The patterns shown are almost exact complements of one another. All patterns are dominated by volatility and suggest multiple processes of evaporation and condensation. However, the lack of large isotopic fractionation indicates that the CAIs did not experience much distillation during their formation. References: (1) Grossman J. *et al.* (1988) *EPSL* **91,** 33. (2) MacPherson G. *et al.* (1989) *Meteoritics* **24,** 297. (3) Kimura M. and El Goresy A. (1989) *Meteoritics* **24,** 286. (4) Ireland T. *et al.* (1990) *GCA,* submitted.

Thick target bombardments: Cosmogenic nuclide production in planetary soil.[a] Peter A. J. Englert,[b,1] S. George Bobias,[1] Darrell M. Drake,[2] Edward R. Shunk,[2] Manfred C. Drosg,[c,2] Robert C. Reedy[2] and Johannes Brückner.[3] [1]San Jose State University, San Jose, CA 95192, USA. [2]Los Alamos National Laboratory. [3]Max-Planck-Institut für Chemie, Mainz, FRG.

Simulation experiments to study the secondary-particle cascade inside a thick target of artificial "martian" soil were performed at the Los Alamos Meson Physics Facility. A steel cylinder with a diameter of 66 cm and a length of 93 cm was filled with a powder having a density of ≈ 1.8 g/cm^3 and a chemical composition close to that from the Viking lander analyses of martian soil. The total water content of this target soil was 3.05%. Monitor foils and other materials were placed upstream of the target, along the target's symmetry axis, and throughout the target volume. For combined measurements of the neutrons escaping from the front of the target (Drake *et al.,* 1990) and of the exposure of elemental targets, the assembly was irradiated with 800-MeV protons for over 40 hours with an average flux of 1 nA. For a detailed study of secondary-particle fluxes, the target was irradiated at the same energy for 12.5 hours with an average flux of about 11.5 nA. Radionuclides made in elemental targets of Ti, Mn, Fe, Co, Ni, Lu, W, and Au were measured by non-destructive gamma-ray spectrometry starting 48 hours after irradiation.

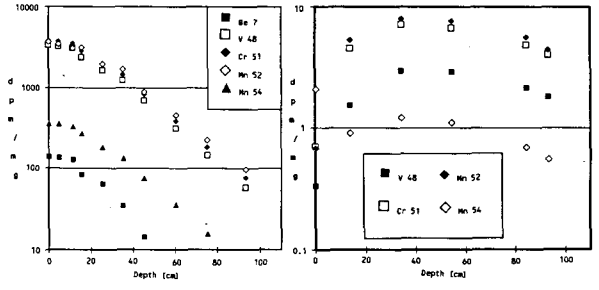

FIG. 1 (left). Spallogenic radionuclides made in iron in the central core.

FIG. 2 (right). Spallogenic radionuclides made in iron in core 11 cm from central axis.

The low to high energy neutron interactions with gold—with and without cadmium—and lutetium are of special interest for the comparison of neutron fluxes measured escaping from the target (Drake *et al.,* 1990) with radiochemical measurements of the neutron cascade in and around the target (Englert *et al.,* 1990). Figures 1 and 2 show activities produced by spallation reactions on Fe as examples of the results obtained. Theoretical calculations and comparisons with other bombardment experiments (*e.g.,* Englert *et al.,* 1987) are in progress. In combination with the leakage neutron measurements (Drake *et al.,* 1990), we expect to get an improved understanding of cosmogenic nuclide production in planetary surfaces. A second target with larger dimensions and lower water content but otherwise similar composition and density was irradiated in July 1990. References: Drake D. M. *et al.* (1990) *Lunar Planet. Sci.* **21,** 300. Englert P. *et al.* (1987) *Nucl. Instrum. Methods* **A262,** 496. Englert P. A. J. *et al.* (1990) *Lunar Planet. Sci.* **21,** 325.

[a]Work supported in part by NASA and done under the auspices of the US DOE.

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Carbon and nitrogen elemental mapping of an iron meteorite. E. U. Engström. Department of Physics, Chalmers University of Technology, S-412 96 Gothenburg, Sweden.

Elemental mapping has been performed of the carbon and nitrogen distributions in the kamacite and taenite in the Agpalilik mass of the Cape York meteorite. Mapping of taenite was carried out when present as lamellae in kamacite and on the kamacite/taenite lamellar structure plessite. Imaging was performed as secondary ion images using a Cameca 3f/4f dynamic SIMS instrument operating in the scanning imaging mode. As a complement to the elemental mapping, line scans of secondary ion intensities were recorded over the mapped areas. O^- and O_2^+ were used as primary ions, and the carbon and nitrogen were recorded on mass numbers 26, 24 and 12, as CN^-, C_2^- and C^-, respectively. Images of Fe, Ni, Co, Ga and P were recorded as $^{54}Fe^+$, $^{60}Ni^+$, $^{59}Co^+$, $^{69}Ga^+$, $^{69}Ga^-$ and $^{79}PO_3^-$.

In the plessite, a positive correlation was established between the Ni concentration and the C and N, while a negative correlation was observed for Fe, Co, Ga and P. Similar observations were made in the taenite lamellae in the kamacite with one exception; Ga showed here a positive correlation with the Ni concentration.

The concentration and isotopic composition of H, C and Si in meteorites. Samuel Epstein. Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA.

Hydrogen exists in meteorites in many different forms. Its isotopic composition (δD values) ranges from $-500‰$ to over 4000‰. With a few exceptions, the hydrogens which are lost upon HF-HCl solution of meteorites have δD values quite similar to terrestrial δD values. The hydrogen in the polymerized organic fraction in meteorites, which is insoluble to HF-HCl solution, is highly variable. The greater the concentration of the hydrogen in the HF-HCl residue, the higher its δD value. This approximate relationship suggested an interstellar origin for the refractory minerals which are a major component of the HF-HCl residue, as well as for the polymerized organic matter. This possibility suggested that different grains of the refractory minerals might be carriers of elements whose isotopic composition reflects their original origin in

the interstellar media and contain elements of unusual isotopic composition. This possibility will be discussed in connection the the $\delta^{13}C$, $\delta^{29}Si$ and $\delta^{30}Si$ in these residues.

The δD values of water-soluble amino acids extracted from the Murchison carbonaceous meteorite have unusual isotopic compositions. The δD, $\delta^{15}N$ and the $\delta^{13}C$ of these amino acids are all higher than the terrestrial values. In particular, the δD values are in excess of 1000‰ and indicate that these amino acids, or their precursors, probably originated from interstellar space. The isotopic data provide clues for the mechanisms of formation of these molecules. References: Epstein S., Krishnamurthy R. V., Cronin J. R., Pizzarello S. and Yuen G. U. (1987) *Nature* **326,** 477–479. Robert F. and Epstein S. (1982) *Geochimica et Cosmochimica Acta* **46,** 81–95. Yang J. and Epstein S. (1983) *Geochimica et Cosmochimica Acta* **47,** 2199–2216. Yang J. and Epstein S. (1984) *Nature* **31,** 544–547. Zinner E. and Epstein S. (1987) *Earth and Planetary Sciences Letters* **84,** 359–368. Pizzarello S., Krishnamurthy R. V., Epstein S. and Cronin J. (1990), in press.

Cr isotope fractionation in inclusions from the Allende meteorite. Tezer M. Esat and S. R. Taylor. Research School of Earth Sciences, The Australian National University, Canberra 2601, Australia.

We have previously demonstrated a correlation between heavy and light Mg isotope enrichment and coarse- and fine-grained inclusion type from the Allende meteorite (1). Coarse-grained inclusions were systematically enriched in the heavy Mg isotopes and the fine-grained inclusions were enriched in the light Mg isotopes. In addition, the inclusions classified as type group II by Mason and Taylor (2), based on REE patterns, appeared to be preferentially fractionated relative to other types and had a heterogeneous distribution of Mg isotopes between spinel and other phases.

We have determined Cr isotope fractionation and ^{53}Cr abundance in seven Allende inclusions with various REE patterns. Interior material from each inclusion was dissolved in HF and HNO_3. The spinels were dissolved separately using a teflon bomb in a microwave oven. The samples were directly loaded without chemical separation. Repeat runs of standards showed that instrumental fractionation could be controlled to within ±1‰ per mass unit. Due to the presence of significant Fe beams the ^{54}Cr abundance could not be determined.

The results of Cr analyses in the seven Allende inclusions are listed in the Table. We have also included Mg fractionation values where available. The data show the following: (i) All inclusions are significantly fractionated in Cr and Mg isotopes in at least one phase. (ii) In each inclusion Mg and Cr isotope fractionations are correlated such that heavy (light) enriched Mg is accompanied by heavy (light) enriched Cr. (iii) In at least two cases, inclusions 3529-21 and 3655B, the Cr isotopes are distributed heterogeneously between the soluble and insoluble (spinel) phases. Inclusion 3529-21 is the first reported case for heterogeneous distribution of isotopes beween co-existing phases in a coarse-grained inclusion. (iv) Fine-grained group II inclusion 3655B appears to be distinct from other group II inclusions in that the spinels are enriched in the heavy Cr isotopes. All other group II inclusions are enriched in the light isotopes both for Mg and Cr in agreement with previous work in Mg.

Further work is in progress to analyse other inclusions and also to determine the ^{54}Cr abundance after chemical separation of Cr from Fe. With the exception of 3655B all fine-grained group II inclusions are enriched in the light Cr isotopes. However, two out of the three coarse-grained inclusions 3529-21 and -45 are also enriched in the light Cr isotopes. It appears that the Cr isotope fractionation in these inclusions does not follow the previously established complementary coarse-grained/heavy isotope, fine-grained/light isotope pattern for Mg isotopes. References: (1) Esat T. M. (1988) *GCA* **52,** 1409. (2) Mason B. and Taylor Smith S. R. (1982) *Contrib. Earth Sci.* **254,** 1.

TABLE. Cr and Mg isotope fractionation in Allende inclusions.

Sample	Fractionation $\Delta(^{25}Mg/^{24}Mg)$‰ AMU^{-1}	Fractionation $\Delta(^{50}Cr/^{52}Cr)$‰ AMU^{-1}	$\delta(^{53}Cr/^{52}Cr)$‰ ±2 s.d.	REE pattern group (coarse (C) or fine (F) grained)	
Soluble portion:					
3529-21	−2.3	+5.9	0.3 ± 0.2	V	(C)
3529-45	−5.8	+11	2.5 ± 0.3	V	(C)
3529-44	+3.0	−4.6	2.2 ± 0.3	VI	(C)
3529-40	−10.1	+6.9	0.5 ± 0.3	II	(F)
3655B	−2.7	−0.8	0.4 ± 0.3	II	(F)
Spinel:					
3529-21	—	+1.1	0.2 ± 0.3	V	(C)
3529-44	+3.0	−5.5	0.1 ± 0.2	VI	(C)
3529-40	−4.8	+5.0	1.2 ± 0.2	II	(F)
3655B	—	−4.6	−0.1 ± 0.2	II	(F)
3529-43	−4.6	+3.8	0.2 ± 0.2	II	(F)
5284	−4.6	+4.6	0.8 ± 0.2	II	(F)

Characterization of noble gases in lunar meteorite Yamato-793274 and radionuclides in MAC88104/5. O. Eugster,[1] J. Beer,[2] R. C. Finkel,[3] J. Hofmann,[4] Th. Michel,[1] A. Synal[4] and W. Wölfli.[4] [1]Physikalisches Institut, University of Bern, Switzerland. [2]Umweltphysik, EAWAG-ETH Zürich, Switzerland. [3]Paul Scherrer Institut, Zürich, Switzerland (on leave from Lawrence Livermore Natl. Lab., Livermore, CA 94550, USA). [4]Institut für Mittelenergiephysik, ETH Zürich, Switzerland.

A sample of 48 mg of lunar meteorite Y-793274 was obtained for noble gas studies. First results are given in Table 1 and compared with ALHA81005. Y-793274 is a mature regolith breccia containing large amounts of trapped solar wind and cosmic-ray produced noble gases; its regolith residence time is several hundred million years. Based on these data a relation between Y-793274 and ALHA81005 is possible. Considering the large distance of about 3000 km between the respective collection sites, pairing is very improbable, but the two meteorites might originate from the same ejection event on the Moon.

Table 2 gives the results of the radionuclide measurements for MAC88104 and MAC88105 using the accelerator mass spectrometer of the ETH in Zürich and, for ^{81}Kr, using one of the noble gas mass

TABLE 1. Solar-wind trapped (tr) and cosmic-ray produced (c) noble gases in bulk samples (10^{-8} cm^3 STP/g).

	$^{20}Ne_{tr}$	$^{36}Ar_{tr}$	$^{21}Ne_c$	$^{38}Ar_c$
Y-793274,66	28 100 ± 1400	12 300 ± 600	37.9 ± 4.0	47 ± 14
ALHA81005[1]	55 900 ± 3100	19 500 ± 1200	32.1 ± 4.1	60 ± 20

TABLE 2. Radionuclide activities in dpm/kg meteorite, except for ^{81}Kr (10^{-15} cm^3 STP/g) and Al concentration (%).

	^{10}Be	^{26}Al	^{36}Cl	^{81}Kr	Al
MAC88104,11	2.3 ± 0.2	*	3.2 ± 0.2	—	18.5
MAC88105,24	1.7 ± 0.1	14.4 ± 2.1	2.8 ± 0.3	29.0 ± 4.3	15.7

* In progress.